STATISTICAL TEST OF RULES FOR DETERMINING POINTS ON SURFACE RIDGELINES FROM WEATHER SATELLITE PHOTOGRAPHS

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ABSTRACT

A method for determining points on surface ridgelines from weather satellite photographs is based on unique cloud forms coincident with the surface ridge. Illustrations of the method are presented. Statistical tests are run on the method to check its validity. The results show an acceptable level of accuracy. Possible problem areas are discussed.

1. INTRODUCTION

Daily studies of photographs taken by weather satellites continue to reveal new ways to use these data as an aid to analysis. One such method that has been suggested by Vincent J. Oliver of the National Environmental Satellite Center is the positioning of the surface ridgeline by characteristic cloud patterns. During the winter of 1966–67 concise rules for locating a point on the surface ridgeline were developed from three characteristic cloud patterns as seen by the ESSA satellites. From these rules two meteorologists, both familiar with satellite picture interpretation, each picked 100 points from various ESSA 3 montages. The 200 test cases were selected over ocean areas where the surface ridgeline points are more numerous than over the continents. No attempt has been made to verify the rules over land. These points were then verified against the surface ridge as analyzed on the National Meteorological Center (NMC) surface chart closest to picture time.

The average difference between the surface ridgeline depicted on conventionally analyzed charts and the point selected from the ESSA 3 montage was used as a measure of the validity of the rules. Standard deviations for the total 200 cases and for each of the three separate rules were computed.

2. THE RULES

TYPE A

On the forward edge of a frontal band, cloud fingers are often tied in a continuous fashion to the frontal clouds [1]. These fingers generally extend in a more southerly direction than the frontal band. Figure 1 is an example of a point on the subtropical ridgeline located on the extreme end of the continuous cloud finger leading into the frontal band.

TYPE B

A point on the surface ridge can generally be found on the western side of subtropical high cells where the clouds change in character from cumulus globs to a more stratified nature [1]. Figure 2 shows points on the surface ridge where the greatest change occurs in the cloud character. This change in cloud character is found where the winds on the western side of the subtropical high cell change direction from southeasterly or easterly to southwesterly or southerly. A thermal change, different amounts of surface heating due to advection of an air parcel northward over colder water, occurs in this region of changing wind direction. Originally, the air was more unstable producing cumulus clouds when heated from below in the southeasterly or easterly flow; it then becomes more stable or less heated from below giving stratiform cloudiness in the southerly current. This difference in heating and stab lity causes the change n the character of the c ouds.

TYPE C

A sharp surface polar ridge is usually wedged between two cyclones in close proximity. There will be a distinct change in the low clouds where the low level wind flow takes on a northerly component. Figure 3 shows the surface ridge positioned along a line where the low level cumuliform clouds first develop in the low level cold air having a northerly component over warmer water.

3. STATISTICAL RESULTS

After the rules were developed, it became obvious that a test of their accuracy was needed. The test consisted of selecting points from ESSA 3 montages that corresponded to points on surface ridgelines according to Types A, B, and C. The latitude and longitude of the points were listed in numerical order and according to type. The

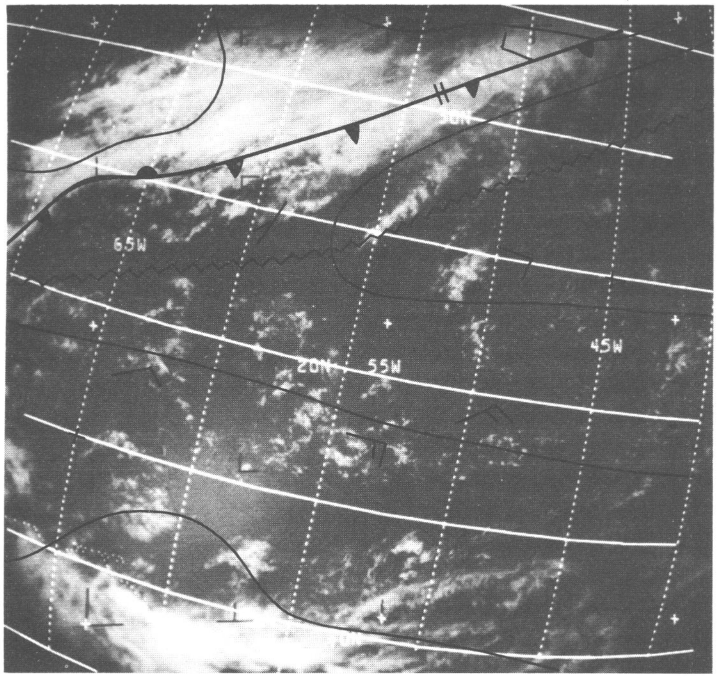

FIGURE 1.—Point on a surface ridge located at the extreme end of a cloud finger at 25°N., 55°W.

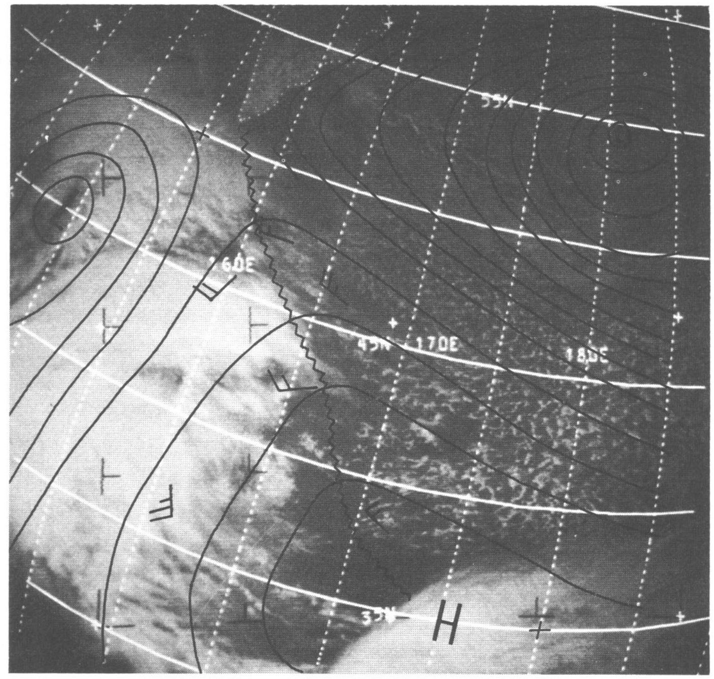

FIGURE 3.—Surface ridge positioned by initial formation of cumulus clouds.

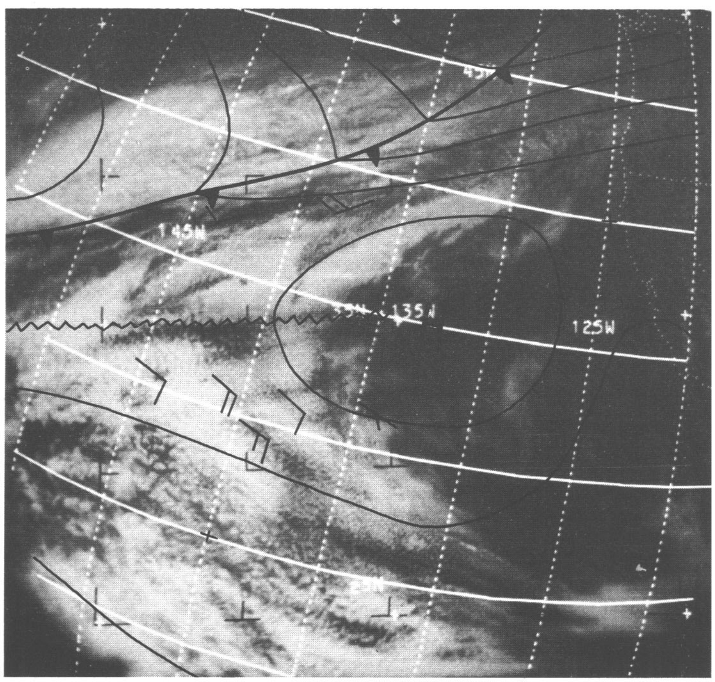

FIGURE 2.—Surface ridge positioned by change in cloud character from 30° to 35°N. between 136° and 150°W.

points were then checked against the position of the surface ridgeline, as analyzed on the NMC surface map closest to picture time. This was done by measuring the perpendicular distance between the point selected from the photograph and the analyzed surface ridgeline. This difference was expressed in degrees of latitude. The differences were listed and averaged for the entire sample and according to each rule. A standard deviation was also computed by the following formula [2] for the entire sample and for each separate rule:

$$S=\sqrt{\frac{1}{n(n-1)}\left[n\sum_{i=1}^{n}X_i^2-\left(\sum_{i=1}^{n}X_i\right)^2\right]}.$$

S is the sample standard deviation, n the number of samples, and X the difference between a point on the analyzed surface ridge and a point on the surface ridge from the ESSA 3 photograph.

Attempts were not made to adjust the surface ridge points, as picked by the analyst, for the differences in times between the photographs and the surface chart. This time difference was never greater than 3 hr. The surface charts were not reanalyzed to make the data points fit better where the analysis was doubtful due to sparse data. Analysts were allowed to select more than one point on a single ridgeline if such points were available. In slightly less than one-half the cases tested, two of the points were on the same ridgeline and four of the cases had three points on the same ridgeline.

The first test consisted of a selection of 100 points during January and early February 1967. Table 1 summarizes the results of these 100 cases with the overall average difference of 1.8°.

A second set of 100 points was selected by another individual from ESSA 3 montages of February through early March 1967. Table 2 summarizes the results of this second set of 100 cases with the overall average difference of 2.1°.

TABLE 1.—*Results of first test*

	Type			
	All	A	B	C
Total	100	44	36	20
Error of ≦ 1°	50	19	17	14
Error of > 1° but ≦ 3°	38	19	13	6
Error of > 3°	12	6	6	0
Average error	1.81°	1.75°	2.10°	0.80°
Standard deviation	1.83°	1.27°	2.16°	.88°

TABLE 2.—*Results of second test*

	Type			
	All	A	B	C
Total	100	45	33	22
Error of ≦ 1°	42	17	13	11
Error of > 1° but ≦ 3°	38	18	12	8
Error of > 3°	20	10	8	3
Average error	2.16°	2.26°	2.50°	1.43°
Standard deviation	2.10°	2.07°	2.44°	1.42°

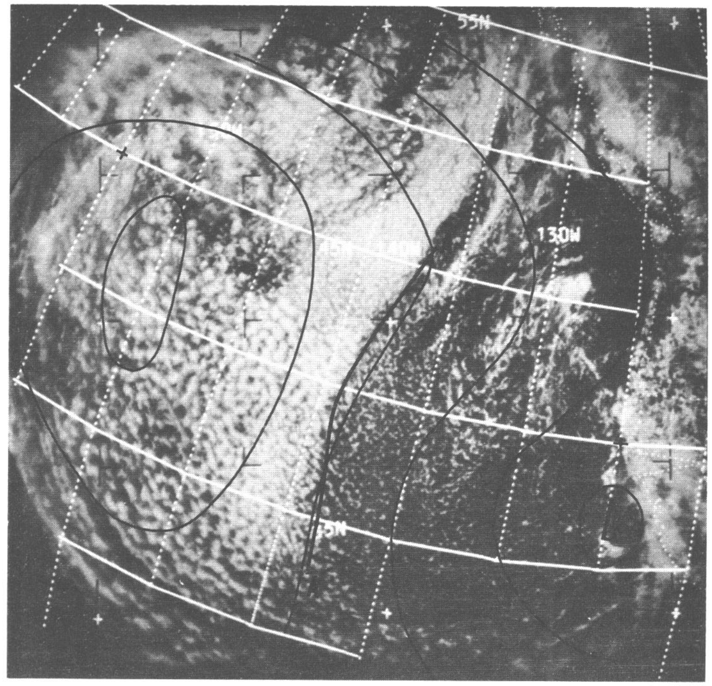

FIGURE 5.—Change in cloud character along line A–A′ that does not represent a surface ridge.

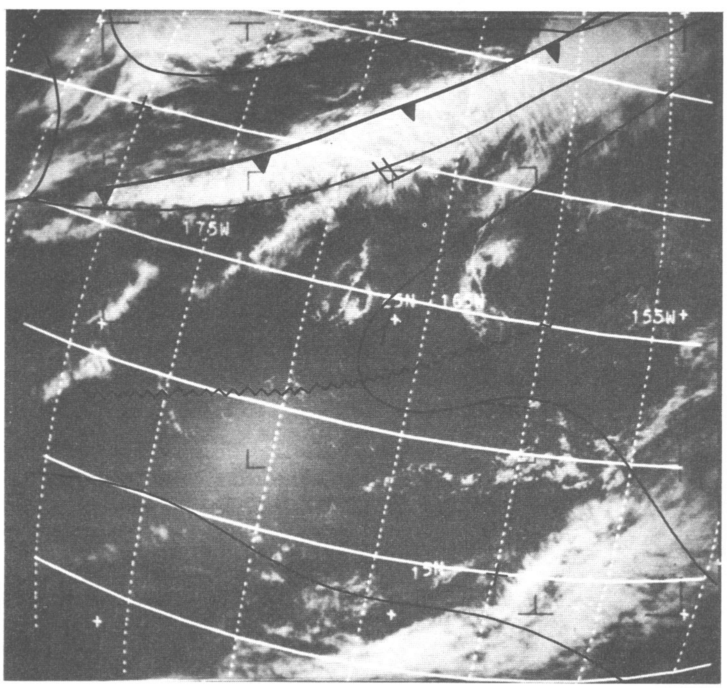

FIGURE 4.—Cloud fingers not continuous with the front.

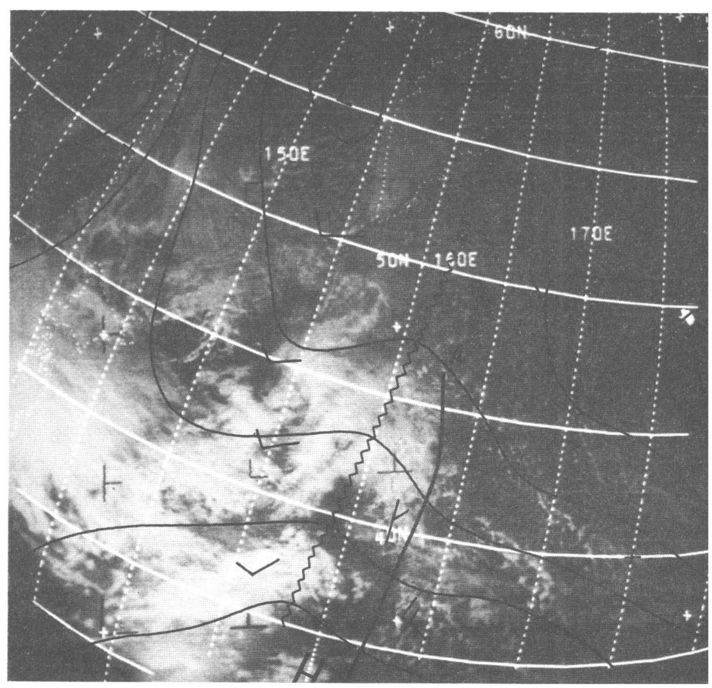

FIGURE 6.—Initial formation of cumulus clouds visible under thin high level cirrus.

For the entire 200 cases there was an average difference of slightly less than 2° between the point selected from the ESSA 3 photograph and the analyzed surface ridge. Type C had the best overall accuracy with an average difference of 1.1°. Types A and B had average differences of 2.0° and 2.3°, respectively. The standard deviation for the 200 cases was 2° with Type C having the smallest standard deviation of 1.2°; Type B, 2.3°; and Type A, 1.7°.

4. PROBLEM AREAS

The accuracy of the surface ridgelines as analyzed by conventional means was considered as a possible factor for these differences. In order to test the accuracy of the NMC analysis, 10 surface ridgelines from Japanese, German, and British surface charts were compared to the corresponding NMC analysis. The comparison of two independent analyses resulted in an average difference in the position of the surface ridgelines of about 1°.

While each of the three types studied had the majority of their differences in the 1° to 3° range, there was a significant number of differences greater than 3°. Many of these larger differences could be traced to a reason peculiar to each individual type which are discussed below.

For Type A, large errors were made when care is not taken in selecting the extreme end of the cloud finger as in figure 4, or where the cloud finger is not continuous with the front.

For Type B, the largest errors occurred where a change in cloud character was associated with a phenomenon other than a surface ridgeline. Along line A-A′ in figure 5 cumuliform appearing open cells change to stratified appearing closed cells. This apparent change in cloud character does not represent a surface ridgeline, but is due to cyclonically curved flow changing to anticyclonically curved flow.

For Type C, the largest errors were made by not determining the initial formation of cold air cumulus. Figure 6 illustrates the importance of determining the initial formation of the low level cumulus clouds. In figure 3 initial formation of low level cumulus is visible along the leading edge of a cirrus deck while in figure 6 the initial formation of low level cumulus is visible through a patch of thin cirrus. If the surface ridgeline, in figure 6, had been chosen along line A instead of line B, a 4° error would have resulted.

5. CONCLUSION

The results of this test, involving 200 cases, demonstrate that the system for determining points on surface ridgelines from satellite photographs has sufficient accuracy to be advantageously applied to surface analysis over ocean areas. These points, used in conjunction with conventional surface reports, will provide the analyst with an accurate position for the surface ridgeline. Many times in the Southern Hemisphere the points obtained by these three rules will be the only data available to position the surface ridgeline. These rules are currently being tested for the Southern Hemisphere and if accurate will prove very beneficial to Southern Hemisphere analysis.

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